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Investigating the Magnetic Properties of the High-Performance Thermoelectric MnTe

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Introduction to MnTe

Manganese telluride is an antiferromagnetic semiconductor with potential applications as a platform for spintronics and a high-performance thermoelectric. When doped with small amounts of Li or Na, its thermoelectric figure of merit *zT* approaches 1, making it a good candidate for waste heat recovery, solid state cooling, and other applications of the thermoelectric effect. The magnetic properties of MnTe are crucial for its promising thermoelectric characteristics. We have therefore undertaken a µSR study of MnTe to shed light on the fundamental magnetic behaviors of this material.

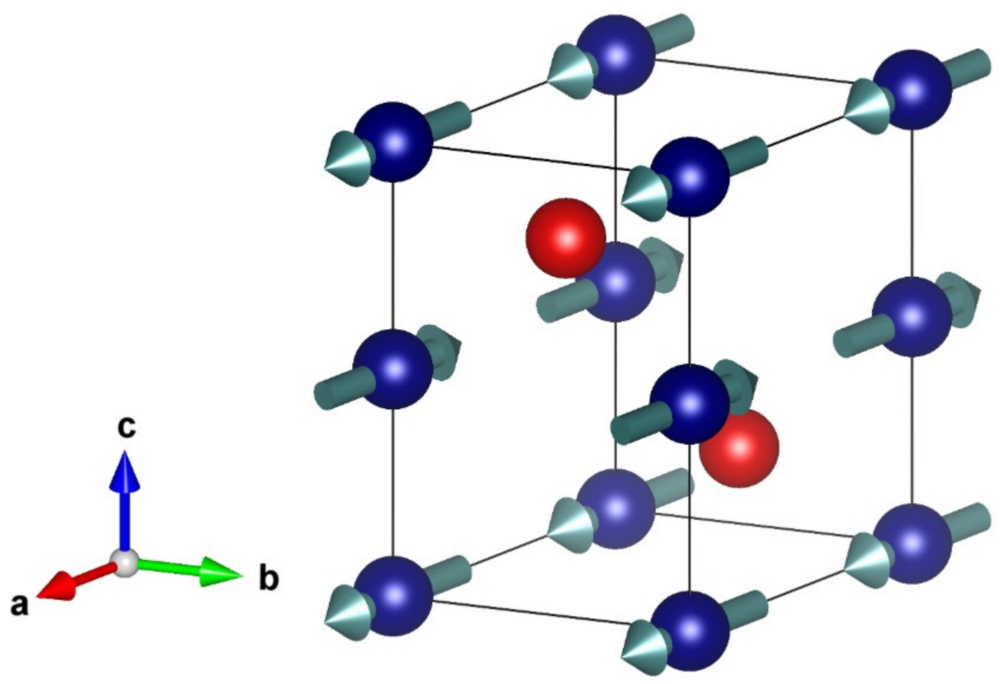

Fig. 1. Crystal and magnetic structure of MnTe.

Experimental Methods

A powder sample of MnTe was synthesized via solid state reaction and pressed into a dense pellet approximately 1.5 cm in diameter. µSR measurements were conducted at TRIUMF on beamline M20D in zero field (ZF) and weak transverse field (wTF) configurations. Two separate sample environments were used: a liquid helium cryostat (2 K – 300 K) and a water circulator (260 K – 450 K) to probe the entire temperature range of interest on either side of the Neel temperature T_N = 307 K. Fits to the µSR asymmetry spectra were performed using least squares minimization as implement in BEAMS, a new python-based program for visualizing and analysis µSR data.

Results: ZF

ZF measurements reveal a sharp transition at 307.5 K with a continuous increase of the spontaneous oscillation frequency as the temperature is lowered through the transition. Minimal relaxation is observed above the transition, indicating that any critical fluctuations of the magnetism are not visible to µSR. The low-temperature asymmetry oscillations develop two distinct frequencies below 250 K. Between 20 K and 80 K, we observe an anomalous depolarization that eliminates the oscillations. The oscillations reappear upon further cooling to 2 K.

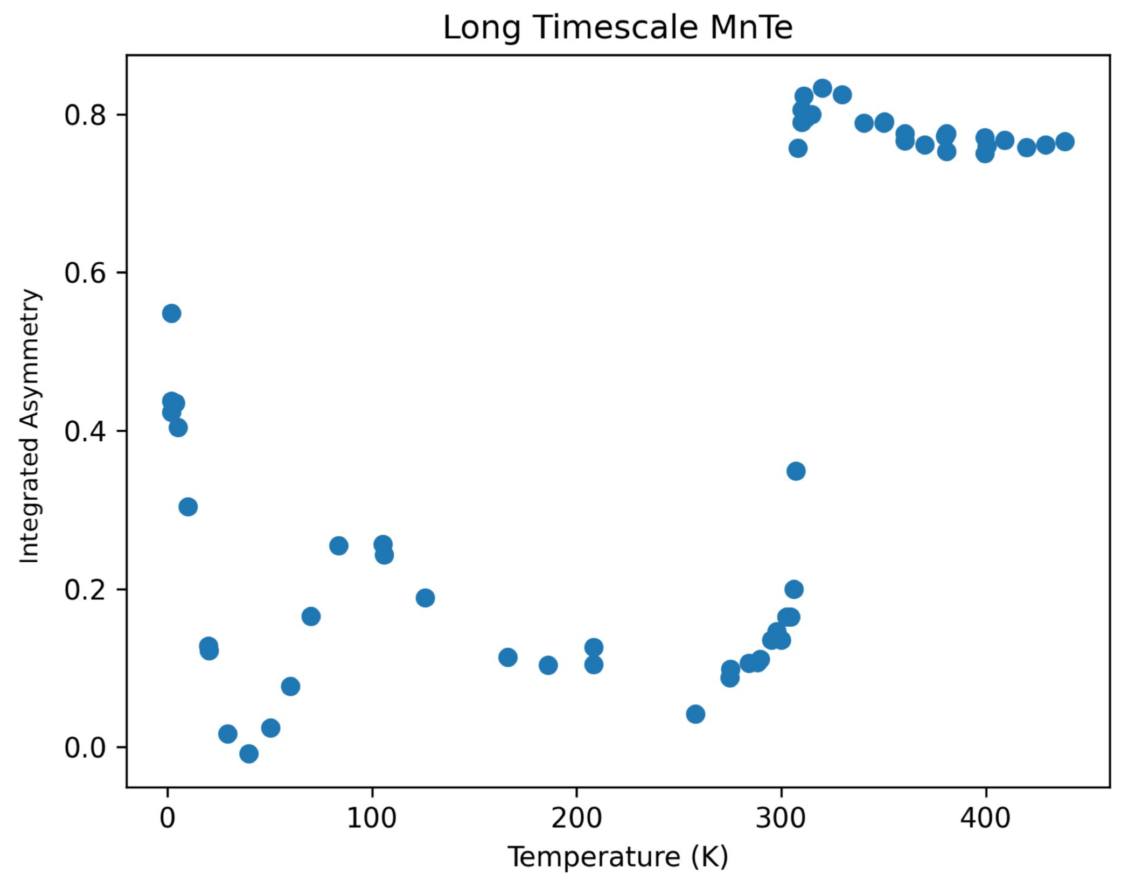

Fig. 2. Time-integrated asymmetry of the ZF spectra as a function of temperature.

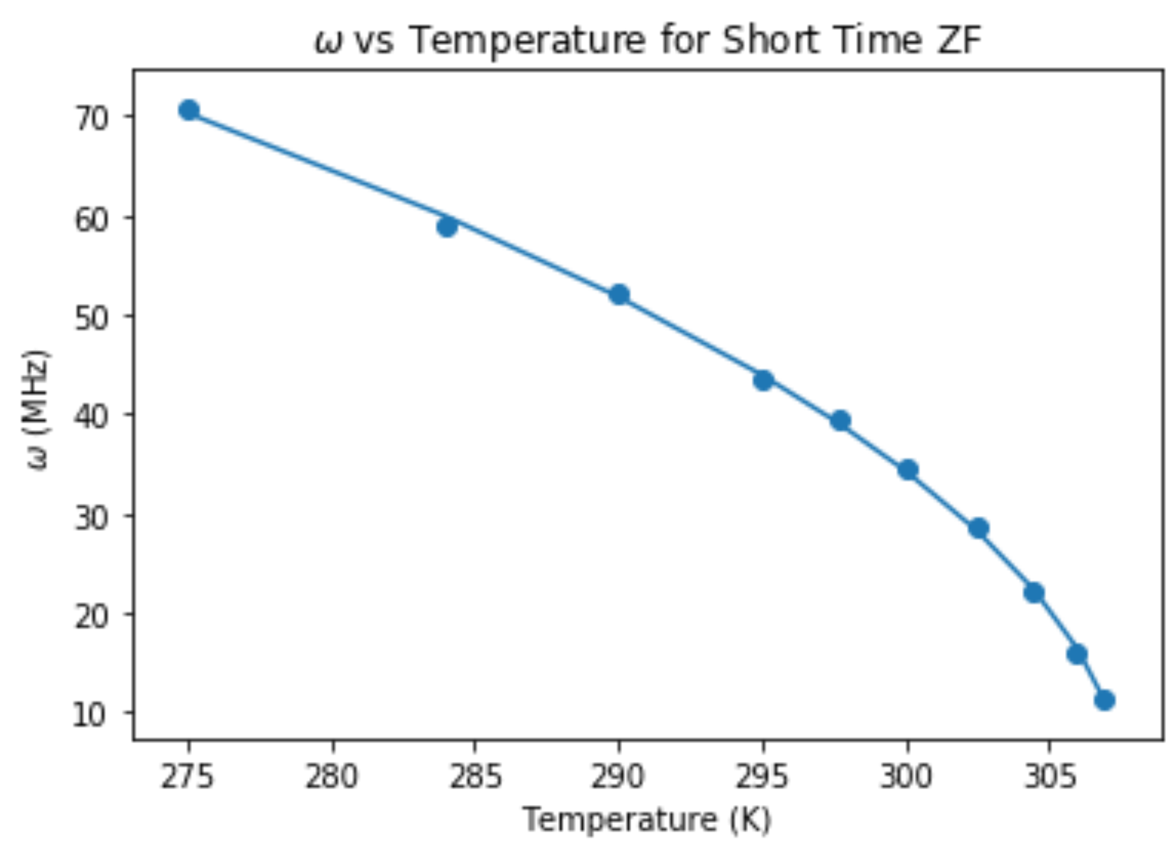

Fig. 3. ZF oscillation frequency showing a continuous phase transition. A power law fit $\Psi(T)=\Psi_0(1-T/Tn)^{\beta}$ yields a critical exponent of 0.5 within uncertainty, consistent with expectations from mean-field theory.

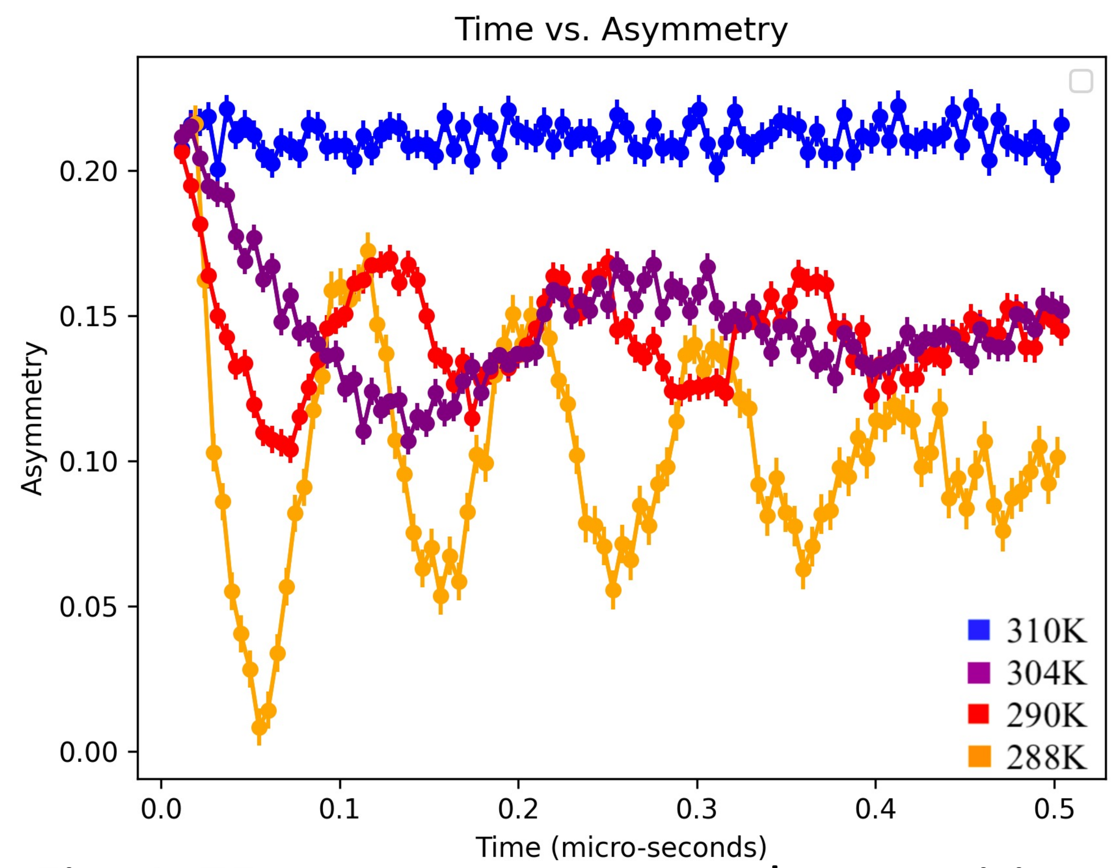

Fig. 4. ZF asymmetry across the transition.

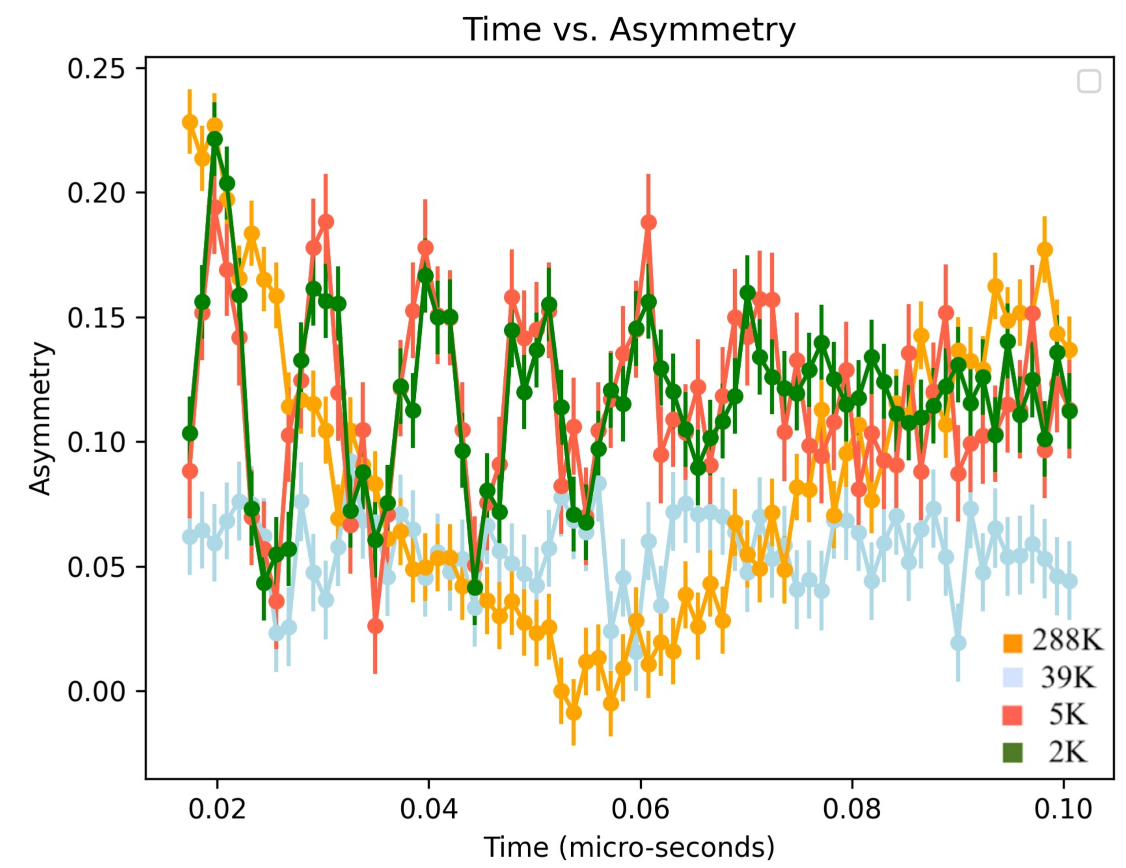

Fig. 5. ZF asymmetry at low temperature.

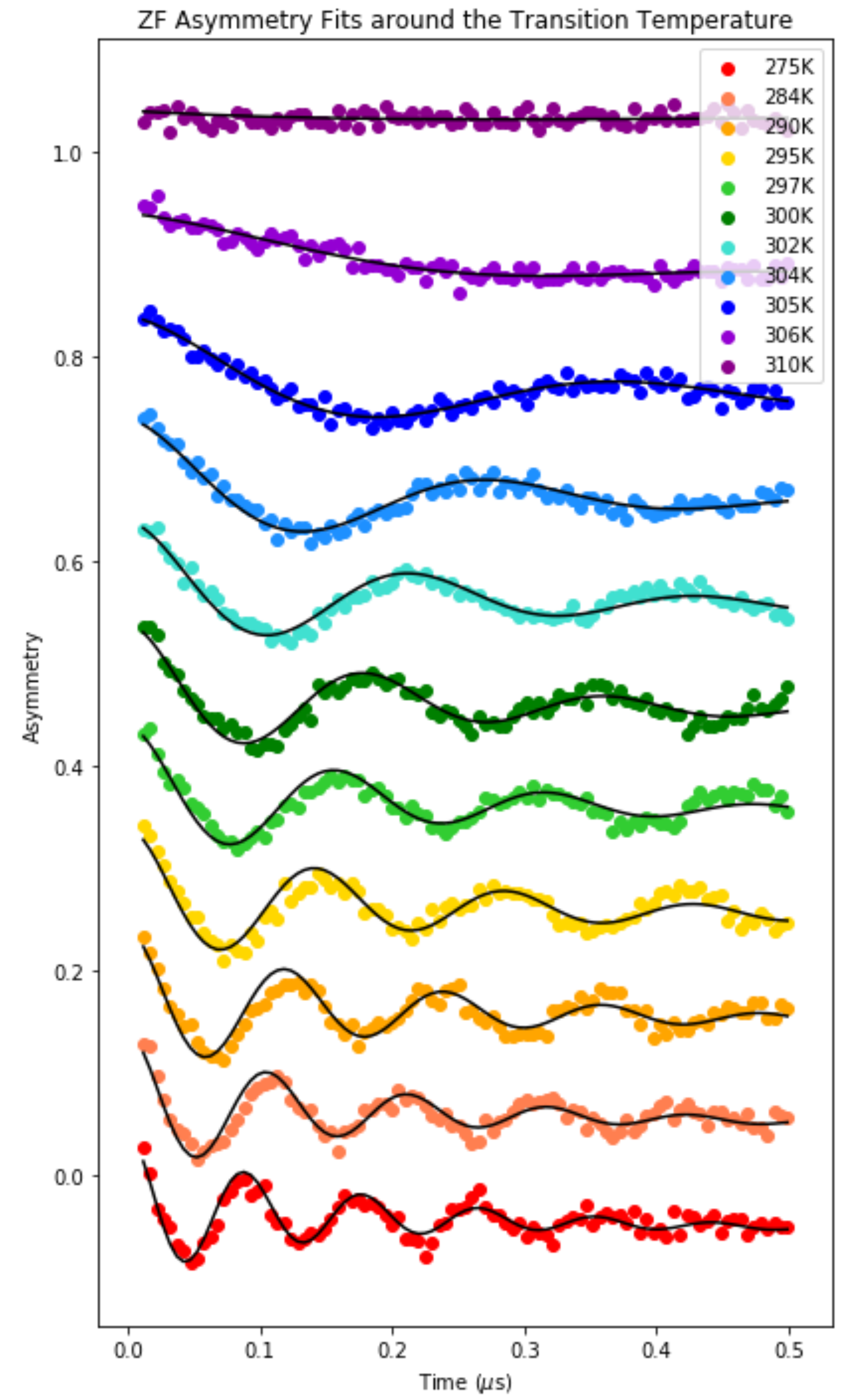

Fig. 6. ZF asymmetry at various temperatures showing the continuous evolution of the oscillation frequency.

Results: wTF

To measure the thermal evolution of the magnetic volume fraction, we performed wTF measurements across the transition. A rapid drop in wTF oscillation amplitude is observed below 307 K, with a gradual further loss down to 280 K, at which point the full volume of the sample is magnetically ordered.

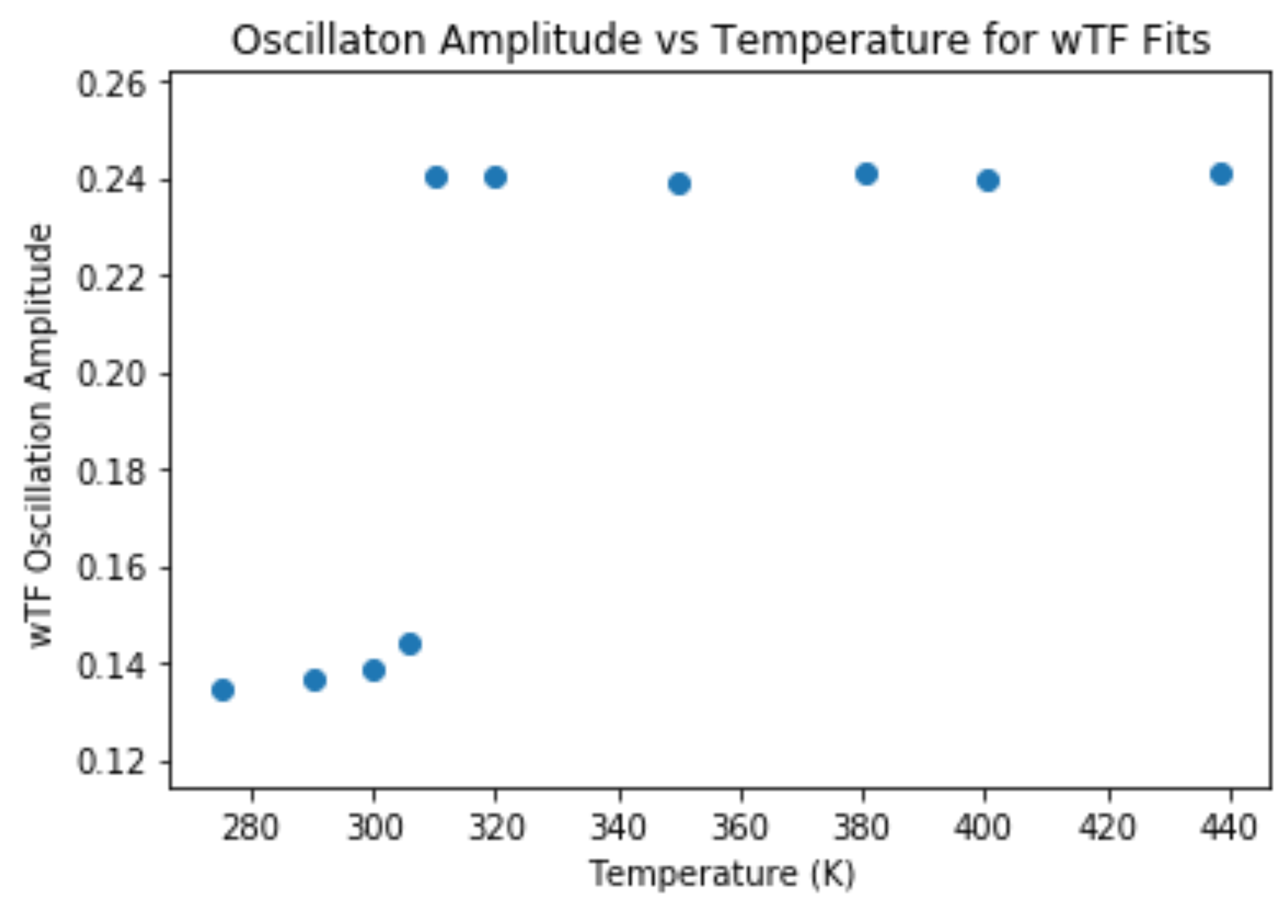

Fig. 7. Amplitude of wTF oscillations.

Discussion and Conclusions

Our µSR experiments on MnTe reveal a continuous magnetic phase transition that occurs at 307.5 K. No evidence for critical slowing down of the spin fluctuations is observed above T_N, suggesting that the short-range magnetic correlations at high temperature that enhance *zT* occur on time scales too fast for µSR to observe. The anomalous depolarization below 100 K is most likely a lattice effect resulting in a repopulation of muon stopping sites. Additional work to understand the rich magnetic behavior of MnTe is ongoing.

Discovery, accelerated